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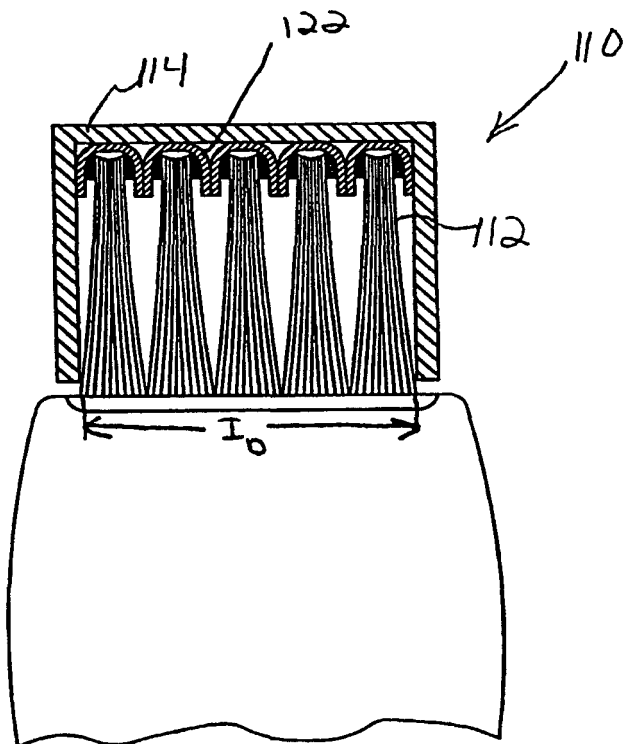
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(54) Title: COMPLIANT BRUSH SHROUD ASSEMBLY FOR GAS TURBINE ENGINE COMPRESSORS



(57) Abstract: A brush shroud assembly for reducing the tip clearance between a rotating blade and an engine casing is disclosed. The assembly includes a plurality of bristle packs supported within a housing such that the bristle distribution at the inner diameter of the bristle packs is substantially continuous. The continuous surface is created by mounting the bristles packs within a housing such that the packs are flared, i.e. width at the outer diameter of the bristle pack is smaller than that at the inner diameter. Various embodiments are disclosed for mounting the flared bristle packs to form a substantially continuous inner diameter. The bristle strips may be mounted in one or more annular rings, may be secured within one or more channels in the housing, the bristle packs may be formed into a tufted ring, or any of these may be utilized in combination with a backplate supporting an abrasion seal, i.e. a hybrid design.

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COMPLIANT BRUSH SHROUD ASSEMBLY FOR GAS TURBINE ENGINE COMPRESSORS

Description

1. Cross Reference to Related Applications

This application claims priority under 35 U.S.C. §119(e) to co-pending U.S. Provisional Patent Application Serial No. 60/246,182, entitled COMPLIANT BRUSH SHROUD CASING FOR GAS TURBINE ENGINE COMPRESSORS, filed November 6, 2000.

2. Technical Field

The invention relates generally to a brush shroud assembly for sealing a gap between an engine casing and rotating blade, and, more specifically, to a brush shroud assembly including a bristle strip having a plurality of bristles mounted in a compliant casing such that the bristles are flared, the flared bristles forming a continuous surface for use in a gas turbine engine compressor to seal a blade-tip flow area.

3. Background of Related Art

Gas turbine engine compressors include an engine casing and a number of rotating blades disposed within the casing. As the blades rotate within the casing, there is a certain amount of clearance between the tip of the blades and the surface of the engine casing in order to prevent the tips of the rotating blades from contacting the engine casing and causing damage to the casing and the blade tips. In aircraft engines, it is desirable to minimize the amount of clearance between the tip of the compressor blade and the engine casing in order to maximize the engine's efficiency. From the standpoint of performance, the blade tip clearance should ideally be zero. However, from a practical standpoint, some tip clearance is necessary to avoid blade tip rub

1 against the casing. The blade tip clearance has a significant effect on the compressor
2 performance including aerodynamic efficiency, pressure ratio, and compressor stall
3 margin. In the past, abradable seals have been utilized between the engine casing and
4 the tip of the rotating compressor blade in order to minimize gap clearance to about
5 .025", as measured between the tip of the rotating blade and the abradable seal.

6 A conventional abradable seal is illustrated in Figure 1. With such seals, a
7 rigid shroud casing 1 usually includes an inner surface having either a felt metal or a
8 soft coating 2, typically sprayed nickel containing graphite. Both types of abradable
9 seals are weak enough to abrade away when contacted by a high speed rotating blade
10 3, without wearing or damaging the blade tip during short-duration rubs, such as rubs
11 which may occur during compressor stalls and hard landings. The designed clearance,
12 "c", of the rigid abradable casing is large enough to avoid frequent rubs. However,
13 during a short-duration rub, the clearance is further enlarged, permanently reducing
14 the compressor performance, such as its efficiency and stall margin. Beyond a certain
15 tip clearance enlargement and performance loss resulting from accumulated rub
16 damage, the engine is removed from service and overhauled.

17 Conventional rigid shroud casings degrade compressor performance as the
18 abradable seal wears away, and also increases the maintenance cost due to frequent
19 engine overhaul and lost service. In order to further reduce the gap clearance and
20 improve performance, a compliant shroud has been developed by Compressor Aero
21 Research Laboratories (CARL), Wright Laboratories WPAFB, Dayton, Ohio, which
22 incorporates staged conventional brush seals, as shown in Fig. 2. In this design, a
23 number of conventional bristle packs 4 are attached to the rotor 5, and are further
24 welded between a rigid front plate 6 and a rigid back plate 7. The bristles are inclined
25 in the direction of rotation, as is conventional with brush seals, and the gap clearance
26 between the tip of the bristles and the tip of the blade is reduced significantly, to about
27 .005". In the event of a blade rub, the bristles deflect elastically and return to their
28 original configuration, thus not enlarging gap clearance. Although the gap clearance
29 is reduced, the clearance of the gap is not continuous since a continuous compliant
30 brush surface is not present, due to the incorporation of front and back plates. The
31 lack of a continuous surface can result in the creation of vortices within the region,

1 thus lowering the compressor efficiency. Another important drawback of the CARL
2 design is that the use of redundant front and back plates significantly increased the
3 weight and cost of the system, which is particularly undesirable in aerospace
4 applications where weight and cost reduction is important. In addition, welding the
5 bristles to the front and back plates can also lead to increased cost, both initially and
6 later, during repairs.

7 A hybrid brush shroud design has also been proposed by CARL, as illustrated
8 in Fig. 3. In this design, a compliant brush casing containing multiple bristles 8 in
9 approximately the front 30% of the chord length is abutted by a rigid shroud ring 9.
10 Using fluid mechanical modeling, it has been demonstrated that the blade tip clearance
11 is critical only in the front section. The tip clearance is significantly reduced in the
12 front section containing the bristle packs. The rear section, containing the rigid shroud
13 ring has an increased tip clearance, in order to prevent blade tip rub. This hybrid
14 structure will reduce the fraction of the blade chord covered with expensive brush
15 shroud, resulting in a lower cost. The brush shroud structure is placed only where it
16 is needed, not the entire chord length. While Figure 3 describes a concept, no design
17 and fabrication methods have been proposed by CARL. In addition, if the rigid
18 shroud ring is contacted by the rotor blade, it can damage both the blade and the
19 shroud ring.

20 Therefore, there is a need in the art a compliant shroud casing which has a
21 good resistance to damage caused by short-duration rotor rubs so as to allow for
22 increased performance overall and less frequent engine repairs due to blade rub, and
23 which is light-weight and cost effective to manufacture and replace, if needed.

24 Summary

25 One object of the present invention is to provide a brush shroud assembly
26 which is inexpensive and easy to manufacture, relatively light weight, and which can
27 be readily replaced, as needed.

28 There is provided herein a compliant brush shroud assembly for reducing the
29 tip clearance between a rotating blade and the engine casing and which improves
30 compressor performance. The brush shroud assembly includes a plurality of bristle
31 packs supported within a housing such that the bristle distribution at the free ends, or

1 inner diameter, of the bristle packs is continuous (i.e. there are no significant gaps
2 between adjacent bristle packs.) The continuous surface is created by mounting the
3 bristles packs within a housing such that the packs are flared, i.e. the width (axial
4 length) at the outer diameter of the bristle pack is smaller than the width at the inner
5 diameter.

6 In one embodiment, the compliant brush shroud assembly having a flared
7 configuration and continuous inner diameter is fabricated by using one or more
8 annular shroud rings which are supported within the housing. Each shroud ring
9 preferably has a U-shaped configuration and may be welded or otherwise joined to a
10 flexible bristle strip fabricated by attaching a plurality of bristle packs to one or more
11 flexible rails. In a second embodiment, the annular ring is eliminated and the flexible
12 bristle strips are secured directly to the housing, through one or more grooves or
13 channels disposed in the housing. In a third embodiment, the flared configuration and
14 continuous inner diameter is achieved by mounting the bristles packs within a holding
15 ring having a plurality of holes to form a "tufted" ring. In a fourth embodiment, any
16 of the first three embodiments (annular shroud ring, insert, and tufted) are utilized in
17 combination with a rigid shroud ring supporting an abradable seal to form a hybrid
18 assembly.

19 Once installed, all of the illustrative embodiments significantly reduce the
20 clearance between the rotating blade and the engine casing as compared with
21 conventional designs. In addition, the modular manner in which the bristles are
22 mounted allows the bristles to be readily replaced, as needed. This can reduce both
23 the labor cost and the cost due to lost service. In addition, by eliminating traditional
24 back and front plates utilized with conventional brush seals, the weight of the above
25 embodiments is reduced as compared to such brush seals.

26

27 **Brief Description of the Drawings**

28 It should be understood that the drawings are provided for the purpose of
29 illustration only and are not intended to define the limits of the invention. The
30 foregoing and other objects and advantages of the embodiments described herein will

1 become apparent with reference to the following detailed description when taken in
2 conjunction with the accompanying drawings in which:

3 Fig. 1 is a partial cross-sectional schematic of an abradable seal of a prior art
4 rigid compressor blade shroud;

5 Fig. 2 is a partial cross-sectional schematic of a prior art compliant shroud
6 utilizing a series of conventional brush seals with rigid front and back plates;

7 Fig. 3 is a partial cross-sectional schematic of a prior art hybrid compliant
8 shroud having brushes mounted in a forward section, and a rigid shroud ring mounted
9 rearwardly;

10 Fig. 4 is a side view of a compliant brush shroud assembly including multiple
11 brush shroud rings, in accordance with a first embodiment of the present invention;

12 Fig. 5A is a cross-sectional view of an annular holder for mounting a bristle
13 strip utilized in the embodiment of Fig. 4;

14 Fig. 5B is a cross-sectional view of a bristle pack mounted between two rails
15 to form a bristle strip;

16 Fig. 5C is a cross-sectional view of an annular holder with the bristle strip
17 mounted therein;

18 Fig. 5D is a schematic of an engine casing with a brush shroud assembly
19 illustrating the direction of blade rotation;

20 Fig. 6A is a cross-sectional view of a bristle pack attached to a single rail to
21 form a bristle strip;

22 Fig. 6B is a cross-sectional view of the bristle strip of Fig. 6A mounted within
23 an annular holder;

24 Fig. 7 is a cross-sectional view of a pair of bristle strips mounted within a
25 single annular holder;

26 Fig. 8 is a cross-sectional side view of a compliant brush shroud assembly
27 including multiple bristle strips mounted within channels in a housing, in accordance
28 with a second embodiment of the present invention;

29 Fig. 9 is a perspective view of a tufted ring of bristles in accordance with a
30 third embodiment;

1 Fig. 10 is a cross-sectional side view of a compliant brush shroud assembly
2 including the tufted ring of Fig. 9 mounted within a housing; and

3 Fig. 11 is a side view of a hybrid brush shroud casing including a brush shroud
4 in a forward section and an abradable seal mounted rearwardly thereof in accordance
5 with a fourth embodiment.

6

7 **Detailed Description of the Illustrative Embodiments**

8 A compliant brush shroud assembly for reducing the gap or clearance between
9 a rotating blade and the engine casing and for improving performance of a gas turbine
10 engine compressor is illustrated in Figs. 4-11. The brush shroud assembly includes
11 a plurality of bristle packs supported within a housing, preferably in rows, such that
12 the bristle distribution at the free ends, or inner diameter (I_D), of the bristle packs is
13 substantially continuous, i.e. there are no significant gaps between adjacent bristle
14 packs at their free ends. Such a continuous bristle distribution enhances compressor
15 performance because gaps are not present between the bristle strips at the surface
16 which engages the rotor blade. In the present disclosure, the continuous surface is
17 created by flaring the bristle packs, i.e. the width at the outer diameter (O_D) of the
18 bristle pack is smaller than the width at the inner diameter (I_D) of the bristle pack such
19 that the O_D is tapered and the I_D is flared relative to each other. To flare the bristle
20 packs, their O_D is constrained and is not continuous, since there are gaps between
21 adjacent bristle packs at the O_D .

22 There are several ways that the compliant brush shroud assembly can be
23 designed with a flared bristle configuration to form a substantially continuous bristle
24 distribution across the width of the shroud. Four exemplary configuration will be
25 described herein below: an annular shroud ring, an insert brush strip, a tufted ring, and
26 a hybrid design. All of these embodiments include the aforementioned flared
27 configuration. As used herein, the term "flared" with respect to the bristle packs,
28 strips, or tufts means that the axial width at the inner diameter (or free ends) of the
29 bristles is greater than that at the outer diameter. As also used herein, the term
30 "bristle" refers to an individual strand, "bristle pack" refers to more than one bristle
31 held together, and "bristle strip" refers to more than one bristle pack held together.

1 In the embodiments which follow, all parts which are the same, or similar to, each
2 other are noted with the same two last numbers, but preceded by a different numeral,
3 depending upon the embodiment. For example, the housing in the embodiment of Fig.
4 1 is numbered 114, i.e. a "1" as the prefix, followed by 14, whereas for the second
5 embodiment the housing would be 214, and so on.

6 In any of the four embodiments discussed herein below, the bristles are
7 preferably angled in the direction of blade rotation (see Fig. 5D). In addition, the
8 bristles may preferably be made of a high temperature alloy, such as a cobalt-based
9 superalloy (for example Haynes 25) to help maintain the shape and orientation of the
10 bristles, and to provide wear-resistance. The clearance between the free ends of the
11 bristles and the tip of the rotating blade can be significantly reduced in any of the
12 embodiments described herein below from the prior art to, for example about .005".
13 As discussed herein above, the corresponding clearance of a conventional rigid casing
14 is much larger, typically .025-.05". During a short-duration rub, such as a compressor
15 stall, the bristle packs deflect away elastically and spring back to restore the designed
16 clearance when the rotor/blade deflection subsides to normal conditions. In contrast,
17 when conventional abradable seals are worn, the clearance is permanently enlarged
18 even after the rotor/blade deflection subsides to normal conditions.

19 Referring now to Figs. 4 and 5A-5C, the first embodiment or shroud ring
20 configuration is illustrated. In this embodiment, the compliant brush shroud assembly
21 **110** having a continuous I_D is preferably fabricated by using one or more annular
22 shroud rings **122** which are supported within housing **114**, as best shown in Figure 4.
23 Each shroud ring preferably has a U-shaped configuration and may be welded or
24 otherwise joined to a flexible bristle strip **124** (Figs. 5A-5C.) In the exemplary
25 embodiment, the flexible bristle strips **124** are fabricated by attaching a plurality of
26 bristle packs **112** between a pair of flexible rails **126a, b** for example by welding, as
27 shown in Figures 5A-5C. After the bristle packs are secured to the rails **126a, b**, the
28 rails are preferably machined to a pre-determined width, such that the bristle strips
29 (including the rails and weld **125**), have a pre-determined width at the outer diameter
30 " O_D " which is less the opening of the U-ring or the annular shroud ring. The bristle
31 strips **124** may then be inserted and secured within the annular shroud ring **122**.

1 The rails are inserted into the channel 128 defined by the ring such that the
2 outer diameter of the rails are preferably in close contact with the inner diameter of
3 the annular holder along the length thereof, and so that the free end 130 of the bristle
4 packs extend from the holder (Fig. 5C). To make the I_D of the shroud assembly
5 continuous, the width of the U-ring, rails and bristle packs at the O_D (W_{OD}) should be
6 less than the width of the free end of the bristle packs at the I_D (W_{ID}). In order to
7 achieve the appropriate dimensions, the bristle packs are compacted or constrained at
8 their O_D by the rails and annular holder to reduce their aggregate width at the O_D .
9 However, the constrained length of the bristle packs is a very small portion of the
10 entire length, so that the bristle packs flare outward toward their free ends. For
11 example, in the present embodiment the constrained length may be 8%-12%,
12 preferably about 10% of the total length of the bristle packs although other
13 percentages may be utilized. Thus, by constraining the O_D to ensure that the W_{OD} is
14 less than the W_{ID} , the bristle strips flare outward, and are wider at their free ends than
15 at the base of the rails. In order to further increase the flared dimensions at the free
16 end, the bristle pack could be further compressed at an appropriate point midway
17 between the bristle length to bend the bristle pack axially outward. For example,
18 pinch rolls may be utilized as a flaring tool to further flare the free ends of the bristle
19 packs. The annular shroud ring and bristle strips are then mounted within housing
20 114.

21 It should be appreciated that while two rails are disclosed, the flexible bristle
22 strips can also be fabricated by attaching the bristle packs to a single, flexible rail 126
23 as shown in Fig. 6A. In addition, multiple strips can be captured in a single U-shaped
24 ring, thereby making the inner diameter more continuous by placing adjacent bristle
25 packs closer together (Fig. 7). Such modifications are within the scope of the present
26 embodiment, as would be known to one of skill in the art.

27 The flexible bristle strips either with double rails or a single rail, can also be
28 directly attached to a housing, for example by welding or brazing. The attachment
29 may be simplified by forming channels in the housing and attaching the bristle strip
30 to the housing, as shown in the embodiment of Fig 8.

1 Referring now to Fig. 8, the second embodiment or insert brush assembly **210**
2 is illustrated. As with the shroud ring configuration, the bristle strips are flared in
3 order to ensure a continuous surface. However, in this embodiment the annular ring
4 is completely eliminated and channels are utilized to constrain the bristle packs. The
5 flexible bristle packs are secured to either a single rail **226** or a double rail (not shown)
6 to form the bristle strips **224**, which are then secured directly to the housing, through
7 a plurality of grooves or channels **232** disposed in the housing **214**. For example,
8 channels may be machined into the housing along an inner, upper edge of the housing,
9 and the bristle strips may be welded or brazed through the channels. Alternately, other
10 manners of forming the channels and attaching the strips therein may be utilized, as
11 would be known to those of skill in the art.

12 The channels **232** and rails **226** may preferably have a stepped configuration,
13 and the rails **226** may preferably extend from within the channels, as also shown in
14 Fig. 8. By extending from within the channels, the rails further contact and constrain
15 the O_D of the bristle strips. As with the first embodiment, the constrained length of
16 the bristle strip is a very small portion of the entire length, so that the bristle strip
17 flares outward toward the free end thereof, making the I_D of the insert shroud assembly
18 continuous. In addition, the stepped configuration of the channels helps to prevent the
19 rails **226** from pulling free from the channel during use. Although the channels are
20 shown as being formed within the housing, as a unitary member, they could also be
21 formed within a separate member and attached to the inner, upper edge of the housing.

22 A continuous bristle pack inner diameter can also be achieved by forming
23 tufted bristle strips, similar to a shoe brush, as shown in Figure 9. Referring now to
24 Figs. 9-10, the third embodiment or tufted ring configuration is illustrated. In order
25 to form the tufted ring, a plurality of holes **334** are machined within a holding ring
26 **336**, for example by drilling. The holes may preferably be formed in rows "r", and are
27 disposed such that they are in close proximity to each other, i.e. in a close-packed
28 pattern, preferably between about 1/10 to 2/10th of an inch apart. The orientation of
29 the holes is preferably offset such that a hole **334a** in one row fall between the two
30 holes **334b**, **334c** in the adjacent rows, in order to allow for the close packing of the
31 holes. The width and the depth of the holes is dependent upon the overall size of the

1 bristle packs which are to be supported therein. The holes operate to constrain the
2 bristles at the outer diameter. As with the previous embodiments, the constrained
3 length of the bristle packs 312 should be a small portion of their entire length, so that
4 the tufts flare open at their free ends 330. The tufts, like strips, can be flared more by
5 compressing the tufts at a point midway between the tuft length. By controlling the
6 size (width and depth) of the holes, the tuft length, and the distance between the tuft
7 holes, the flared ends of the tufts can be made to contact each other thereby generating
8 a continuous surface at the I_D , as shown in Fig. 10. It will be appreciated that the size
9 of the tufts, the size and the spacing of the holes may (and should) be varied, so that
10 the surface is continuous, as would be known to those of skill in the art. After the holes
11 are formed in the holding ring, metallic bristle packs can then be inserted into the
12 holes, and a plurality of rings may be arranged in parallel and inserted within housing
13 314. The final inner diameter of this brush shroud assembly may then be precision
14 machined using Electro Discharge Machining or other similar processes such as
15 plunge grinding.

16 Any of the previously described embodiments, the shroud ring configuration,
17 the insert configuration, or the tufted ring configuration, may be utilized in
18 combination with a backplate supporting an abradable seal to form a hybrid design.
19 Referring now to Fig. 11, the fourth embodiment or hybrid assembly 410 is illustrated.
20 As with the previous embodiments, the bristle packs are flared in order to ensure a
21 continuous surface. However, in this embodiment the bristle strips having a
22 continuous surface extend for only about 25-50% of the length ("L") of the housing
23 414. The remaining 50-75% of the length of the housing preferably supports a back
24 plate 338 having an abradable seal 340 supported on an inner surface 342, and
25 preferably made from either a felt metal or a soft coating, as is conventional.

26 In the embodiment of Fig. 11, the flexible bristle strips 424 are mounted within
27 annular shroud rings 422 and supported within the housing 414, as described above
28 with respect to the first embodiment. However, it will be appreciated that the flared
29 bristle strips may be supported within the housing in alternate manners, for example
30 through channels or tufted rings as described above. By combining the flared bristle
31 strips having a continuous surface with the abradable seal, the gap clearance can be

1 decreased in both the forward and rear section, because the wearing away of the
2 abradable seal during short duration rubs will not interfere with performance due to
3 the inclusion of the flared bristle strips in the forward portion of the housing. This
4 embodiment is expected to have a lower cost and weight than the previous
5 embodiments because the combined weight of the back plate, abradable seal and
6 bristle strips should weigh less and be less expensive than the bristle strip assemblies
7 alone. In addition, the cost of use can expected to be less because the bristle strip
8 assemblies are expected to be replaced less often than conventional abradable seals,
9 and the cost to replace the bristle strip assemblies described herein is also expected to
10 be less than that of conventional bristle packs. Also, the abradable seal need not be
11 replaced just because the gap clearance has become larger, since the continuous
12 surface resulting from the forward mounted flared bristle strips should maintain the
13 compressors performance within acceptable limits.

14 It will be appreciated that the compliant brush shroud assemblies described
15 herein all have a good resistance to damage caused by short-duration rotor rubs so as
16 to allow for increased performance overall and less frequent engine repairs, are
17 relatively light weight and cost effective to manufacture and replace, if needed.

18 It will be understood that various modifications may be made to the
19 embodiment disclosed herein. For example, the dimensions given are approximate
20 may be changed, as would be known to those of skill in the art. Also, the materials
21 utilized may be substituted, as appropriate. In addition, although an annular holder
22 is shown and described as U-shaped, it should be understood that the annular holder
23 may take other configurations. For example, the holder may have an L-shaped
24 configuration, with the bristle strip being secured to the holder such as by tack
25 welding. In addition, pieces which are shown or described as unitary may be formed
26 separately, and vice versa. Also, the brush shroud assembly may be used for land
27 based applications, as well as the aerospace applications specifically disclosed herein.
28 Therefore, the above description should not be construed as limiting, but merely as
29 exemplifications of a preferred embodiment. Those skilled in the art will envision
30 other modifications within the scope, spirit and intent of the invention.

31

32 WHAT IS CLAIMED IS:

CLAIMS

- 1 1. A compliant brush shroud assembly for use with a gas turbine engine, the
2 brush shroud assembly comprising:
3 a housing;
4 at least two bristle packs including a first end defining an outer diameter and
5 being constructed and arranged to be secured within the housing, and a second end
6 opposite the first end defining an inner diameter, the bristle packs being constrained
7 at the first end and free at the second end such that the width at the outer diameter is
8 less than that at the inner diameter and the second end is flared relative to the first end;
9 and
10 wherein upon securing the bristle packs within the housing the free second
11 ends of adjacent bristle packs forms a substantially continuous surface.
- 1 2. The assembly of claim 1, wherein the bristle packs are secured to at least one
2 rail so as to form a bristle strip.
- 1 3. The assembly of claim 2, wherein the bristle packs are supported between a
2 pair of rails.
- 1 4. The assembly of claim 2, further comprising an annular ring and wherein the
2 bristle strip is supported within the annular ring such that an outer diameter of the at
3 least one rail is disposed adjacent an inner diameter of the annular ring, the free second
4 ends of the bristle packs extending from the annular ring and having a width greater
5 than the width of the bristle strip and annular ring combined.
- 1 5. The assembly of claim 4, wherein the annular ring is generally U-shaped.
- 1 6. The assembly of claim 4, wherein two or more bristle strips are supported
2 within a single annular ring.

1 7. The assembly of claim 2, wherein the housing includes one or more channels
2 disposed therein, the channels being constructed and arranged to support the bristle
3 strips.

1 8. The assembly of claim 7, wherein the one or more channels have a stepped
2 configuration.

1 9. The assembly of claim 7, wherein the one or more rails extend from within the
2 channels.

1 10. The assembly of claim 1, further comprising a holding ring having a plurality
2 of holes constructed and arranged to support and constrain the first end of each of the
3 bristle packs.

1 11. The assembly of claim 10, wherein the plurality of holes are formed in rows,
2 the rows being offset from each other such that a hole in a first row falls between
3 adjacent holes in a second row.

1 12. The assembly of claim 1, wherein the constrained portion of the bristle pack
2 has a length of about 10% of the total length of the bristle pack.

1 13. The assembly of claim 1, wherein the bristle packs are supported within a first
2 portion of the housing for about 25-50% of a total length of the housing, and a back
3 plate having an abradable seal is supported within the remaining 50-75% of the length
4 of the housing.

1 14. A compliant brush shroud assembly for use with a gas turbine engine, the brush
2 shroud assembly comprising:
3 a housing;
4 at least two bristle packs, each including a first end defining an outer diameter
5 and being constructed and arranged to be secured within the housing, and a second end
6 opposite the first end defining an inner diameter, the bristle packs each being free at

7 the second end and constrained at the first end, the constrained portion extending for
8 about 10% of a total length of the bristle pack as measured between the first and
9 second ends, so that the width at the outer diameter is less than that at the inner
10 diameter and the second end is flared relative to the first end; and

11 wherein upon securing the bristle packs within the housing the free second
12 ends of adjacent bristle packs forms a substantially continuous surface.

1 15. The assembly of claim 14, wherein the bristle packs are secured to at least one
2 rail so as to form a bristle strip.

1 16. The assembly of claim 15, further comprising an annular ring and wherein the
2 bristle strip is supported within the annular ring such that an outer diameter of the at
3 least one rail is disposed adjacent an inner diameter of the annular ring, the free second
4 ends of the bristle packs extending from the annular ring and having a width greater
5 than the width of the bristle strip and annular ring combined.

1 17. The assembly of claim 16, wherein two or more bristle strips are supported
2 within a single annular ring.

1 18. The assembly of claim 14, wherein the housing includes one or more channels
2 disposed therein, the channels being constructed and arranged to support the bristle
3 strips.

1 19. The assembly of claim 14, further comprising a holding ring having a plurality
2 of holes constructed and arranged to support and constrain the first end of each of the
3 bristle packs.

1 20. The assembly of claim 19, wherein the plurality of holes are formed in rows,
2 the rows being offset from each other such that a hole in a first row falls between
3 adjacent holes in a second row.

- 1 21. The assembly of claim 14, wherein the bristle packs are supported within a first
- 2 portion of the housing for about 25-50% of a total length of the housing, and a back
- 3 plate having an abradable seal is supported within the remaining 50-75% of the length
- 4 of the housing.

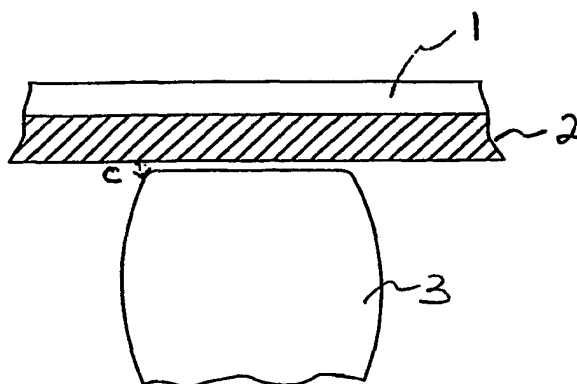


FIG. 1
(PRIOR ART)

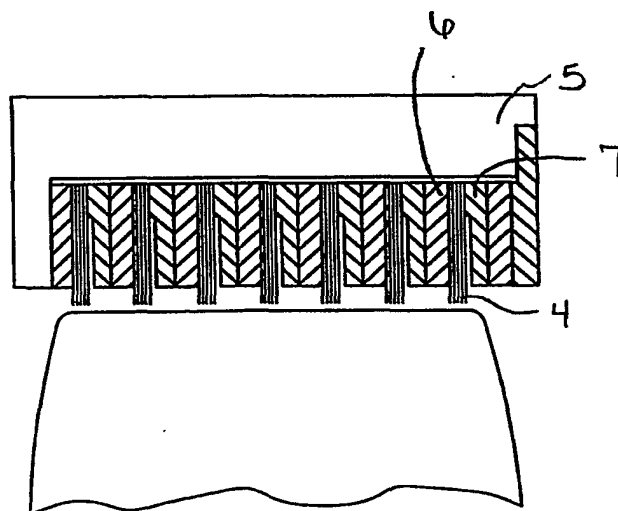


FIG. 2
(PRIOR ART)

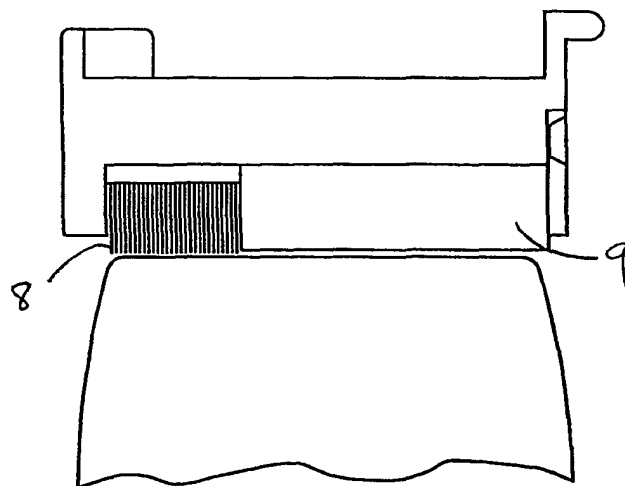


FIG. 3
(PRIOR ART)

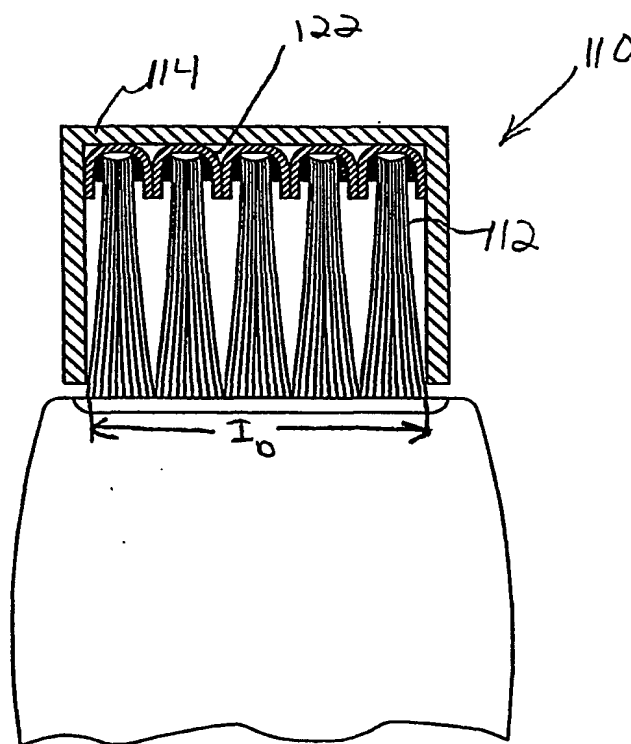


FIG. 4

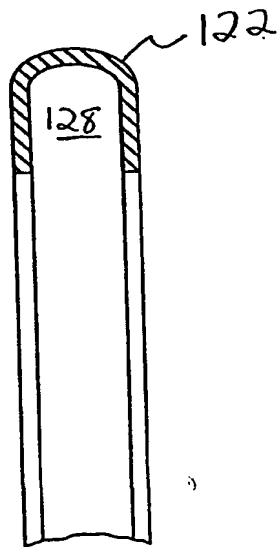


FIG. 5A

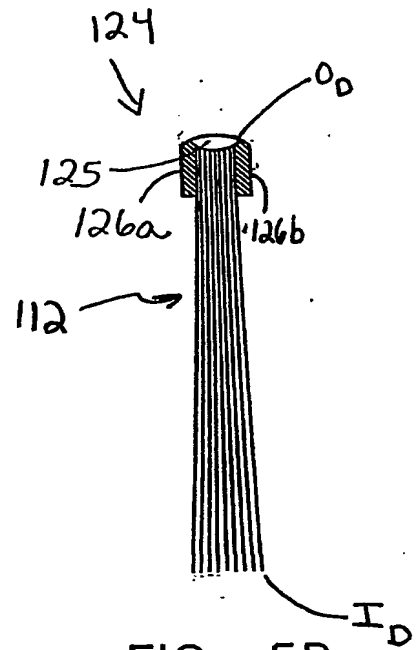


FIG. 5B

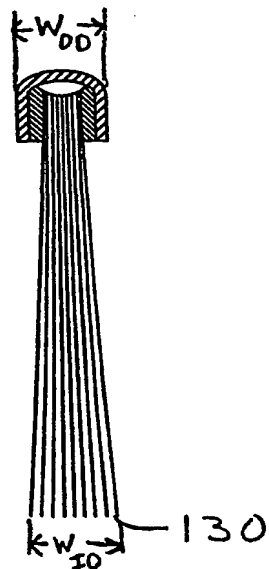


FIG. 5C

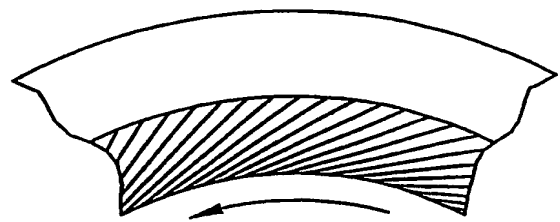


FIG. 5D

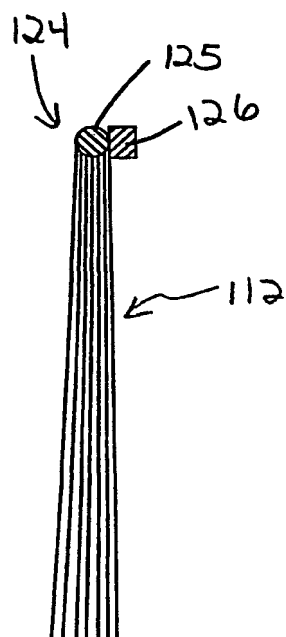


FIG. 6A

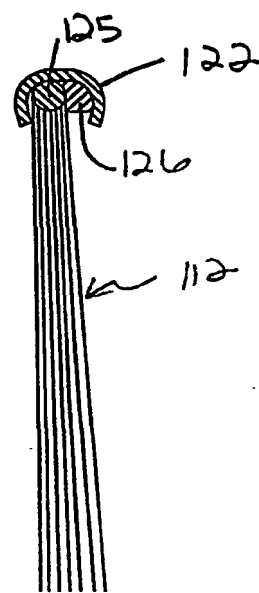


FIG. 6B

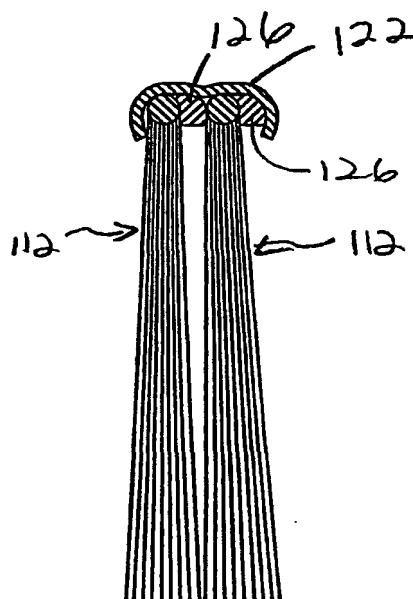


FIG. 7

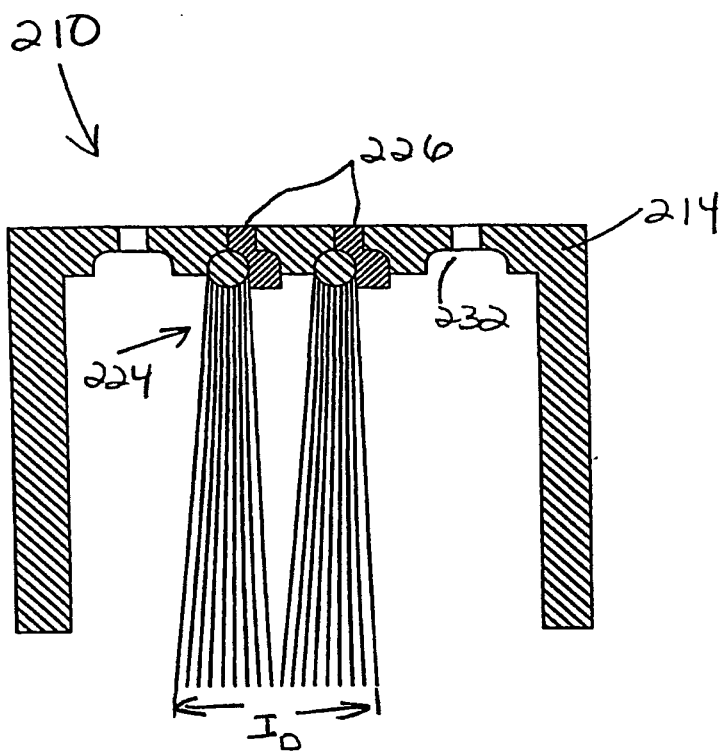


FIG. 8

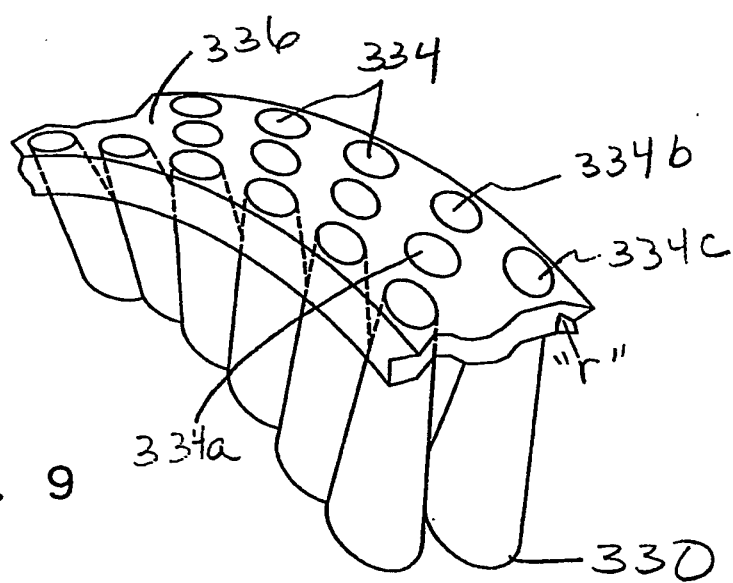


FIG. 9

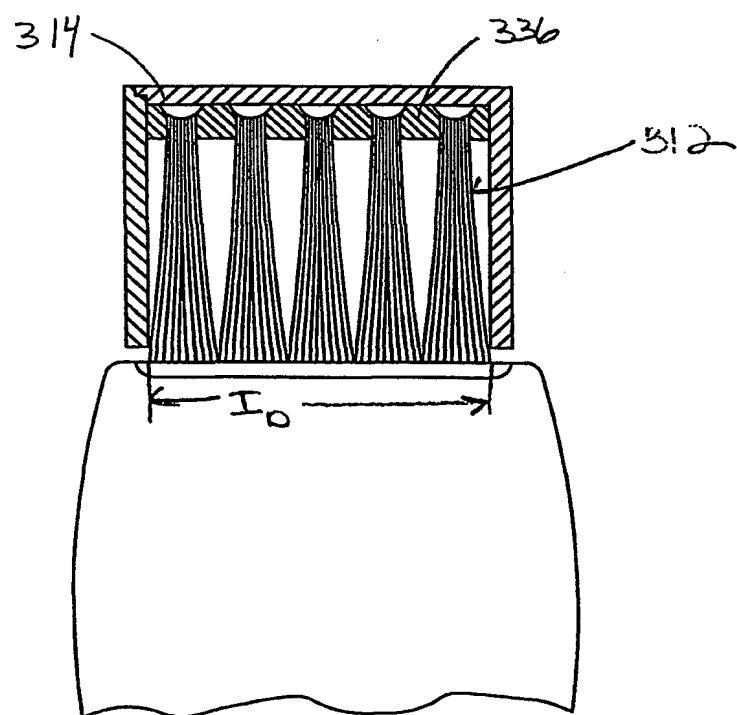


FIG. 10

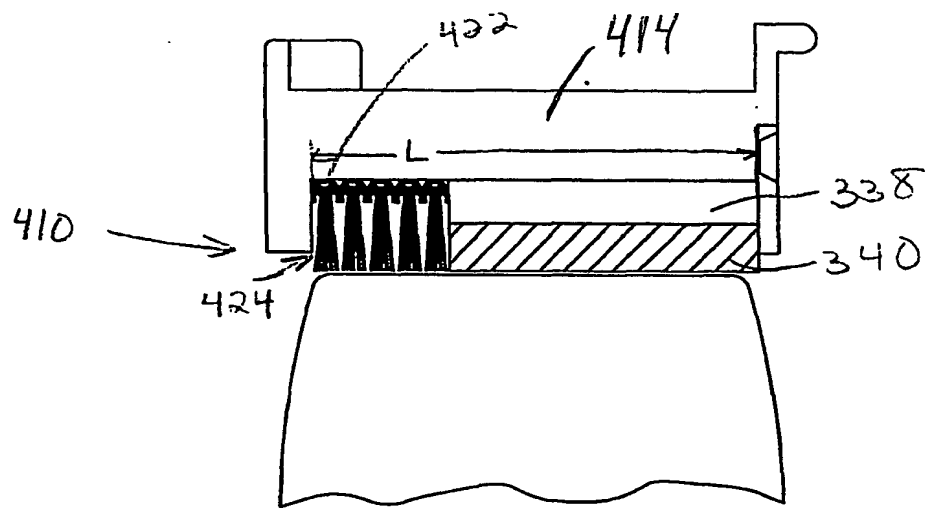


FIG. 11